Strategy Research Project

MANAGING UNCERTAINTY: RISK MANAGEMENT IN ACQUISITION

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USAWC STRATEGY RESEARCH PROJECT

MANAGING UNCERTAINTY:
RISK MANAGEMENT IN ACQUISITION

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ABSTRACT

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The defense acquisition system may be improved through tough, sometimes controversial, decision making based on risk. Three areas of risk management will be examined in the form of good projections of technology maturation, achievable requirements, and producibility. Technology maturation risk will examine the technologies being pursued by major defense acquisition programs and whether the available technologies were underdeveloped at Milestone B based on technology readiness levels (TRL). The requirements investigation will examine how well the program was able to define requirements, map requirements against achievable near term technology, and keep requirements from expanding beyond the core set needed for the mission (what many refer to as “mission creep”). Producibility risk, defined as the ability to produce end items within the projected cost and schedule, will be examined in terms of overall program cost and schedule growth or program restructurings. Some major defense acquisition programs as case examples will be examined to determine influencing factors that affect program acquisition that are beyond the ability of the program office to control. Recommendations are included for areas of further study.

MANAGING UNCERTAINTY:
RISK MANAGEMENT IN ACQUISITION

President Obama signed into law on May 22, 2009, the Weapons Systems Acquisition Reform Act of 2009, and in his signing remarks stated "…the Weapons System Acquisition Reforms Act, represents an important next step in this procurement reform process. It reforms a system where taxpayers are charged too much for weapons systems that too often arrive late -- a system that suffers from spending on unproven technologies, outdated weapons, and a general lack of oversight."[1] Acquisition reform has been ongoing since the Civil War, to improve the management of the weapons procurement process.[2] The acquisition process has been faulted for not adequately addressing immature technologies ("unproven" in the President's words), requirements changes in the midst of a program, and the uncontrolled costs of a program's affordability.[3]

In 2008, the Government Accountability Office (GAO) assessed 96 programs with an average cost growth of 26 percent over initial acquisition costs, 44 percent with an increase in per unit cost greater than 25 percent and an average schedule delay of 21 months.[4] Cost overruns and schedule delays are indications that programs are complex and difficult to manage as measured against initial baseline cost and schedule estimates. Cost and schedule growth are symptoms of underlying issues that add risk to program management. Program risk in three areas will be examined with regard to using immature technology, expanding requirements and the inability to meet affordability goals.

This research paper examines the risk management process within the defense acquisition process. The risk management process will be defined as understood by the Defense Acquisition University, which is the training institution for the acquisition career field within the Department of Defense.[5] The risk management process will be examined for the ability to address technology risk, requirements change, and the cost or affordability of programs.

Risk Management

Risk is a measure of future uncertainty in the ability or inability to achieve program objectives within costs, schedule, and technical performance parameters.[6] Risk has two components, a present probability that a future risk will occur and a consequence or effect if that future risk occurs.[7] So, risk management is about managing **future** events, and is not about managing current issues or present problem solving.[8] Risk management is about prioritization and concentrating program resources on the high impact, high probability risk.[9] As such, it proactively informs the Program Manager on where to spend valuable resources, money, time, people or technology, rather than reacting to problems as they arise. Risk management is a continuous process of managing perceived future risk to the program by a multi-function team.

Risk management consists of four major steps that examine risk: risk planning, risk assessment, risk handling and risk tracking (see figure 1). Risk planning is concerned with implementing a strategy that develops a team-based, collaborative process, a documented and agreed upon method to identify, categorize, track and revisit risks throughout the life cycle of a program. A plan should include a method to address level of severity, probability of occurrence, and responsibilities of team members, and frequency of meeting. The plan should also document how to initiate

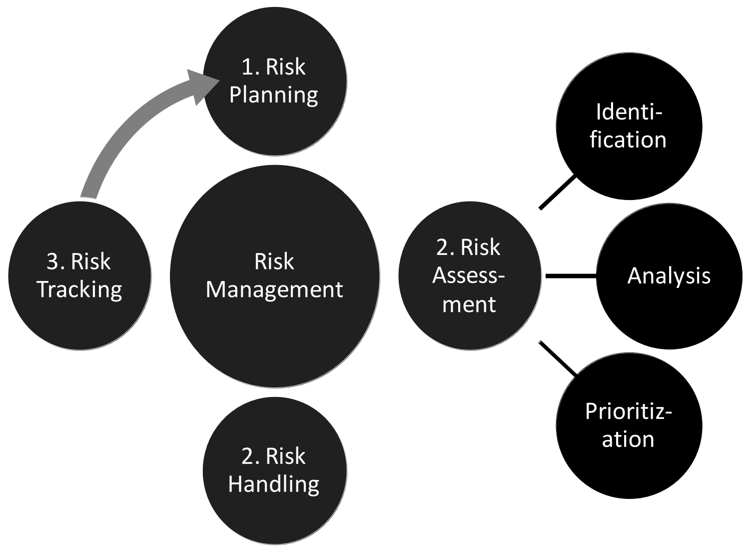

Figure 1. Risk Management Cycle[10]

the tracking and identification of new risks. Because risk is not limited to the technical management of a program, team members should be from every portion of the acquisition community and program management office: management, procurement, resource management, technical or engineering, security, legal, acquisition, test, requirements and the industry partners where appropriate.[11] Areas that may be addressed in a risk management strategy include budget, schedule, performance, contracting, political will, strategic direction, internal meeting and communications processes, technology, requirements, manufacturing technology, software, integration complexity, material, work breakdown structure, decision processes, documentation, and quality control to mention the most common.[12] Not all of these are required or necessary; they are project dependent.

Risk Assessment involves three steps: risk identification, risk analysis and risk prioritization. Risk identification is based on program requirements from various sources including the user's requirements, contracting, testing, performance work statements, design drawings, integration, technology development, manufacturing technology as well as the objectives for cost, schedule and performance and other source documentation.[13] The program objectives in technical, operational and business processes are assessed for sources of risk, both internal and external.[14] Internal risks are within the scope of the program to manage, such as ensuring interoperability. External risks are those beyond the internal control of the program management office, such as a political shift that may impact funding. The intent of any risk identification and analysis is to identify the root cause of the risk, and associate it with the part of the program's work breakdown structure where the risk will be managed.[15] An analysis provides a concise statement of what the risk is and what its future impact is for that element of the work breakdown structure that has the risk assigned.[16] These risks are managed using a risk register which is reviewed periodically, and can be computer-based programs.[17] Risks occur throughout the program, from early on with technology risk to later on in production as manufacturing technology is more relevant.[18] The process for maintaining a risk register is a part of the responsibilities of the risk management team. The register contains the risk, consequence, and action needed to address the risk.[19]

The last step in the assessment process is risk prioritization. To manage the risk, a prioritization method is used to rank the probability of a risk occurring and a level of potential impact or consequence.[20] For instance, if the risk is very low and the consequence or impact to the program is very high, resources may be allocated to measure and monitor the risk and not allocated immediately to implement action to mitigate the risk. Various scales and ranking methods are used. The scales are associated with thresholds established by the risk management team for the level of consequence that is considered acceptable.[21] This process allows a risk

Probability						
	5	Green	Amber	Red	Red	Red
	4	Green	Amber	Amber	Red	Red
	3	Green	Amber	Amber	Amber	Red
	2	Green	Green	Green	Amber	Amber
	1	Green	Green	Green	Green	Green
		1	2	3	4	5

Consequence (Severity)

	Probability			Current Process		
5	Near Certain	80–100%	1	Cannot Prevent	No Alternatives	Seek New Technology
4	Highly Likely	60–80%	0.1	Cannot Prevent	Alternatives	Mitigate
3	Likely	40–60%	0.01	May Prevent	Action Needed	Control
2	Low Likelihood	20–40%	0.001	Probable Prevent	Monitor	Measure
1	Not Likely	0–20%	1.00E-06	Will Prevent	Monitor	
	Consequence Category	*Performance*	*Cost*	*Schedule*	*Utility*	
5	Very High	Failure	>25%	year	100%	
4	High	Severe Impair	>15%	6 months	60%	
3	Medium	Modest Impair	>10%	3 months	40%	
2	Low	Slight Impair	>5%	1 month	20%	
1	Very Low	Minor Impair	<2.5%	< 1 month	<20%	

Figure 2. Example Risk Matrix with Probability and Consequence Definitions.[22]

matrix to be displayed that cross references high likelihood and high consequence risk to clearly identify risks that may need management plans to mitigate. See Figure 2 for an example matrix, associated definitions for probability and consequence, and the endnotes for a more detailed explanation. Prioritization assists the risk management team to assess the projected risk and allocate its resources on the more probable and realistic risks that may have an impact on the program.[23]

Once the risks have been identified and prioritized, the risk management team and the program management office are able to plan to handle the risks. Risk handling involves developing mitigation strategies for reducing the occurrence or severity of the identified risks. The possible strategies are avoidance, transference, control and assumption, either used by themselves or in combinations. The avoidance strategy seeks to choose alternative approaches to the cost, schedule or performance risk in order to eliminate the risk from occurrence, for instance, choosing a less risky technology concept. Transference is about reallocating risk within the system, and relies on system design techniques, such as modularity, to transfer risk to a single module or function in order to concentrate resources on that function or module. Risk control is about reducing or mitigating risk to reduce the probability of the risk occurring or lessen the impact on the program. An example of risk control is using multiple development efforts to develop several possible designs so that if one design proves intractable to develop, other designs are available to achieve the same desired performance. Lastly, risk assumption is acceptance of the risk and is usually reserved for consequences and probabilities that are relatively low, recognizing that program resources are better used on the higher risk categories. The plan uses these strategies, and then uses risk tracking through the use of appropriate metrics to monitor risk occurrence. [24]

Risk tracking uses the results of metrics developed for use that will ideally be constructed to indicate early warning of risk, based on cost, schedule and performance or other risk category. Some measurement techniques are test, earned value management, schedule performance, program metrics and technical performance measurements among others. Risk tracking may also discover additional risks, which then may be addressed with a robust risk management process, to establish a risk level.[25]

Risk management is another tool for the program manager, to inform and be tailored based on the needs of the program. The process provides a structured way to examine risk and provide information on a continuous basis to make informed decisions.[26] Risk management does not replace the attention to detail and structured decision process required in well managed acquisition programs.[27]

Analyses of defense and public sector infrastructure programs demonstrate that all programs have risk and that risk is manageable.[28] Cost and Schedule variance are common program management metrics used to monitor program progress.[29] The manifestations of risk as schedule delays, cost increases or performance shortfalls are common to all large projects; defense and public sector.[30] In the major studies of defense related programs, risk is categorized into three areas that the program managers may be able to influence: technology selection and use, realistic requirements generation and producibility or cost effectiveness.[31]

<u>Technology Risk</u>

Technology risk is risk associated with choosing technologies, integration of technologies or software development, or manufacturing technologies. Within the DOD, the technology risk for major parts of programs are assessed by ranking the technology against a preset scale from one to nine in defined technology readiness levels (TRL), with nine being the most mature and proven technology in real mission environments and one being basic research.[32] To be assessed as a mature technology ready for the engineering and manufacturing development (EMD) phase, a TRL level of six or above is desired, prior to entering into system development.[33]

To illustrate technology risk, consider five programs, consisting of the Army Tactical Missile System (ATACMS), a deep strike missile, Javelin, an anti-tank missile, the Future Combat System (FCS), a suite of systems, the Joint Direct Attack Munition (JDAM), a guidance package for unguided bombs, and the F-22 Raptor, an advanced tactical fighter. The technology risk for these programs will be examined in terms of programmatic symptoms of risk in schedule and cost impacts and program restructures.

Table 1 provides a comparison of selected programs. ATACMS and JDAM were two programs that entered the EMD phase with a more significant portion of technologies at level six and above. ATACMS and JDAM, albeit, smaller in scope than

Program Aspects	ATACMS		Javelin		FCS		JDAM		F-22	
	Evolutionary		Single-Step		Evolutionary		Single Step		Evolutionary	
Ultimate Capability	Deep Attack		Fire & Forget		Networked Force		Precision Guidance		Tactical Fighter	
Subsystem	Critical	TRL > 6	Critical	TRL > 6	Critical	TRL > 6	Critical	TRL > 6	Critical	TRL > 6
(at Milestone B)	6	6	7	0	31	1	6	6	unknown	unknown
		(4 at 9)		(5 < 6)						
Cost of Development	~$700M		~$700M		~$22B		~$380M		~$11B	
	Months		Months		Months		Months		Months	
Tech Development Phase	0		27		16		0		54	
Advanced Development Phase — Planned	48		36		32		46		41	
Advanced Development Phase — Actual	51		54		56		40		59	
Total Time in Development	51		81						113	
Schedule Growth	6%		50%		57%		0		44%	
Cost Growth	0%		150%		76%		-25%		85%	EMD
Program Restructures	unknown		unknown		5		1		5	

Table 1. Program Technology Readiness and Cost and Schedule Growth.[34]

FCS and the F-22, experienced significantly smaller or no schedule and cost overruns. ATACMS and JDAM used technologies that were mostly well understood prior to entering EMD. ATACMS borrowed the M74 bomblet, solid rocket motor, fin surface flight control and inertial guidance system technologies from the family of Multiple Launch Rocket System (MLRS) rocket programs, which have been in development production since 1983.[35] All of these are proven TRL level 9 technologies that were incorporated into the early stages of the ATACMS program.[36] Likewise, JDAM used more mature technology at the outset, over 85 percent of the JDAM components were from commercial sources already producing the technology.[37]

In contrast, Javelin, FCS and the F-22 had several immature technologies on entry into the equivalent EMD phase. Javelin entered EMD with no critical technologies at TRL level 6.[38] The Javelin program was using a single-step program within EMD to achieve a revolution in seeker technology with imaging infrared and software-driven automatic target tracking and engagement, and a missile with soft-launch capability, neither of which was available at the beginning of the program.[39] As a consequence, the Javelin program's development schedule was lengthened by 2 years and cost growth was 150 percent higher than the initial baseline.[40] FCS was into the program's fifth year, after four years of technology development and a full year into EMD, before technology risk mitigation plans were even in place for the critical technologies needed to produce FCS.[41] Even at milestone B in 2003, FCS had 31 identified critical technologies where 30 were below level 6 or system or sub-system demonstration in a relevant environment.[42] The number of critical technologies increased to 49 in 2006 with 18 reaching TRL level 6.[43] As late as 2008, the FCS network architecture technology was assessed as immature.[44] The F-22 program technology risks involved avionics integration, a new supercruise engine with thrust vectoring and a low radar cross section airframe with composites. The airframe and avionics experienced 42 and 25 percent cost growth from 1996 to 2002, respectively.[45] The program also experienced schedule delays of up to a year for delivery of airframes due to airframe manufacturing difficulties.[46] The technology associated with these programs was immature technology at Milestone B and has a correlation with program cost and schedule overruns.

Although technology alone is not responsible for cost and schedule overruns, evidence of immature technology contributing to program risk exists. When this is coupled with management decisions to allow entry into EMD with immature technology, or is not accounted for in risk management and planning, program costs and schedules begin to increase. Management decisions that impacted programs negatively occurred in both the FCS and F-22 programs. In the FCS program, risk management was not complete until a full year into the EMD phase of the program.[47] The delayed effort at risk management planning coupled with the 32 of 33 immature technologies contributed to cost and schedule increases that ultimately led to five program restructurings. FCS entered EMD with immature technologies with the agreement of the decision makers. The F-22 program, in comparison to the F/A-18 E/F program, had only a small management reserve, and was operating on the over-optimistic planning that technology was not a risk, which proved inadequate for the airframe and the avionics integration, both of which caused significant delays in the program.[48] In order to enter into development, technology assessments for maturity should be included as part of the review needed for Milestone B decisions. Early in the program, prior to milestone B, technology maturity should be an element of the risk management plan and added to the risk management process. Although immature technology is a risk that contributes to program cost and schedule overruns, other areas of risk impact programs, such as changing requirements in the midst of EMD.

Requirements Risk

Requirements risk is often due to requirements instability. Requirements instability is represented as poorly defined and changing requirements during the development of the system. In DOD and intelligence community (IC) programs, requirements instability has contributed directly to cost and schedule growth.[49] In the case of the Space-Based Infrared System High (SBIRS-High), new requirements were being added well into development, and were poorly defined at the start of development.[50] A billion dollar cost growth to the program was attributed to requirements growth and definition.[51] In the FCS program, three years into product development (2006), system level requirements were still in flux.[52] Requirements should be well defined at Milestone B. In the Advanced Extremely High Frequency (AEHF) communications satellite program, cost growth of $0.72 billion was attributed to requirements that were added to the program after May of 2000.[53] In the Joint Surveillance and Target Attack Radar System (JSTARS) Common Ground Station (CGS), not only were requirements added, two versions of the station, a light and medium, were added to the program after development was underway.[54] One version was terminated for affordability reasons after a few years in development.[55] In a study of 13 Army programs, those that experienced requirements changes in mid development experienced 50 percent less favorable performance outcomes than those programs that did not experience requirements changes.[56] Favorable performance outcomes were defined as meeting technical requirements and cost and schedule goals.[57]

Requirements instability impacts program cost and sometimes schedule growth. However, holding requirements firm, resisting increases in requirements, and holding life cycle times to short time periods, improve the chances of program performance on cost and schedule.[58] Those programs that met cost and schedule goals were able to achieve two outcomes: short development times and clearly defined requirements at program development start.[59] Requirements as a source of instability should be considered within the context of risk planning and an effort made to control increases to existing well defined requirements.

The Joint Capabilities Integration and Development System (JCIDS) is the DOD requirements approval and definition process that approves major defense acquisition program requirements.[60] The JCIDS process has been characterized as slow to achieve approval as well as being service parochial.[61] Most programs are validated by the Joint Requirements Oversight Council (JROC).[62] The requirements approval process is not linked with the ability of the acquisition community to provide feasible technology within funding constraints.[63] DOD is implementing a Milestone Decision Authority (MDA) review at program initiation to examine technology feasibility and affordability, as outlined in the 2008 DOD Instruction 5000.02.[64] Efforts at linking the funding, requirements and acquisition processes for better informed decision making have potential to improve the complex environment that procures materiel for the forces.

Producibility Risk

Producibility is defined as meeting cost and schedule goals. Risk increases when costs or schedules increase buying less weapon systems for the funding spent. Several GAO reports have demonstrated program cost growth is due to requirements instability or technology immaturity or both and that cost growth is a symptom of these underlying causes.[65] In general, cost growth in a program is identified by schedule delays, increased costs per unit production, or less production for the funding.[66] The FCS and F-22 programs demonstrated cost growth from immature technologies. Requirements increases affected the cost of several satellite programs.[67] The cost increase has in a number of programs resulted in fewer production end items that increase the average per unit procurement cost (AUPC).[68] Other factors that may contribute to growth in AUPC, are unrealistic initial costs driven by the "low-bid" syndrome. The low bid syndrome is the desire by a contractor to procure the contract by producing an unrealistic baseline cost for the development of the program.[69] The consolidation of the defense industry may be exacerbating the bidding process. The bid process may not be an accurate reflection of the true cost of the program. Another possible cause of increased AUPC is the financial instability. If the program was funded, and that funding was reduced from external causes, the AUPC will increase when less funding is available and quantities are reduced.[70] Other effects from funding instability include personnel turnover and testing schedule changes that often result in increasing costs or schedules or both.[71] Affordability is impacted by funding stability, outside intervention into a programs funding, the low-bid process.

Cost and schedule increases to program affordability are not themselves root causes of affordability risk. The identification with root causes for affordability risks are essential in being able to determine the increasing lack of affordability in DOD weapons acquisition programs. The identification of the root cause of the funding instability aides in determination of risk mitigation actions. For example, like the FCS and F-22, the Stryker and Javelin programs experienced affordability issues. In the Stryker program technical armor and weight issues with the Mobile Gun System (MGS) were the root cause of cost increase.[72] In the Javelin program, the seeker technology maturity was the root causes of the program affordability issues.[73] Both programs had cost and schedule increases. The cost and schedule increases are metrics that allow a program manager to track affordability risk of weapons programs and should be monitored as indicators. They can be risk mitigated, by allocating management funding reserves and time reserves in the early planning of the schedule.

The Planning Programming Budgeting and Execution (PPBE) system also has impacts. In the case of the F-22 the AUPC was pushed upward by decisions to decrease from 750 to 648 aircraft in 1990, and then to 442 in 1994, and then to 339 in 1997 when congress imposed a cost limit to production for affordability reasons as costs for the program continued to rise.[74] The final numbers were based on existing budget and capped the program at 187, with the recommendation of Defense Secretary Gates.[75] Both program costs and decisions from outside the program office increased the AUPC.

Risk Management and Managerial Influence

In a few cases, programs have managed to achieve performance cost and schedule outcomes. In those cases that achieved favorable outcomes, JDAM, ATACMS and MRAP, risk mitigation strategies that contributed to favorable results will be examined.

JDAM employed a number of techniques at risk mitigation. One was to ensure that the program held a rigid mission performance and requirements process consisting of seven fixed and untradeable Key Performance Parameters (KPPs) to avoid increases or changes in requirements.[76] This approach requires two methods, a well defined initial set of requirements as a baseline, and no new requirements after the Preliminary Design Review (PDR).[77] Another technique employed by the JDAM program was to rigorously avoid any effort at over-design from the contractor development, using 85 percent commercial and government off-the-shelf technologies.[78] The use of these technologies also contributed to the ability of the program to use mostly mature technologies.[79] Affordability risk was controlled through a rigid cost control program that added Average Unit Production Price (AUPP) as a KPP.[80] The use of commercial or GOTS sources provided the government with cost benefit trades and alternatives to meet the AUPP KPP.[81] The affordability of JDAM using average unit price may be because JDAM is an expendable package with low-to-no maintenance needs.

JDAM implemented two processes under acquisition reform that transferred risk to the contractor: configuration control and a warranty.[82] The contractor was responsible to maintain designs, and to provide a warranty on performance of 20 years shelf live and 5 years service life, accepting the risk of maintaining quality to comply with the warranty.[83] The use of Integrated Process Teams (IPTs) in close partnership with industry to provide immediate feedback on performance from both test programs and design performance enabled changes on the contractors' designs to reduce cost and increase performance.[84] The IPT process paid dividends when the program underwent the only restructuring as a result of flight instability on the Mk-83 and BLU-

109 JDAM kits discovered in testing, delaying kits for about one year.[85] The IPTs resolved the flight instability. As will be shown later this same process provided benefits on MRAP**.** The Joint Air-to-Surface Standoff Missile (JASSM) is another missile program that used similar techniques, like using proven technology in the engine and imaging sensor, solidifying requirements, and making cost a KPP, all of which achieved similar results.[86]

ATACMS used technologies that were very mature, TRL levels of 6 or higher, with many at TRL level 9, having been borrowed from the MLRS program. ATACMS uses a modular independent architecture compatible with the M270A1 and High Mobility Artillery Rocket System (HIMARS) fire control and launchers, building on the MLRS program.[87] The use of mature technologies, a well defined and limited set of requirements and the short duration of the program aided the ATACMS program office in achieving production on schedule and within budget.[88] ATACMS experienced no late engineering changes, achieved system unit costs, met the program technical requirements, and experienced no significant issues during deployment.[89]

The Mine Resistant Ambush Protected (MRAP) vehicle program implemented a risk management strategy to mitigate risk to the program.[90] In order to achieve production quantities, multiple vendors with multiple designs were needed.[91] The test and evaluation program was designed as a risk reduction and mitigation part of the program.[92] The test and evaluation was designed to test the most critical capabilities first, followed by others later.[93] As part of the process, contractor-IPTs were conducted by the program office to identify any changes that could be incorporated into the designs for the next block of production, so a test-fix-test program was used to provide risk reduction. [94] Also, MRAP identified two material flows early in the development that could impede production - domestic armor supply and tires rated to fifteen tons.[95] Law requires that domestic armor be procured for military vehicles from either domestic suppliers or Canada.[96] The program obtained a waiver to procure armor from overseas vendors in order to achieve production quantities.[97] Tires were another risk identified. The program approached a second manufacturer to produce additional tires, and approached the Defense Logistics Agency (DLA) to produce more tire molds.[98] Both were needed to produce tires for production and as spares as MRAP vehicles were fielded.[99]

MRAP had other material requirements and approached the DOD to receive a DX rating to compete with other major programs for materials and spares.[100] The program anticipated integration as risk. The program approached Space and Naval Warfare Systems (SPAWAR) Charleston to assemble Government Furnished Equipment (GFE) into MRAP vehicles. SPAWAR effectively became a central shipping point for installation of all GFE and attained integration rates of 50 vehicles a day.[101] With Charleston Air Force Base, an airlift capable airfield, and Charleston Naval Base, a naval port that allowed MRAPs to be quickly shipped as production approached a thousand vehicles per month, within six miles of SPAWAR, Charleston was an ideal central integration site.[102]

Since MRAP was DOD's first priority program, many of the oversight and decision processes were assisted by the program's priority. The amount of funding has propelled MRAP to DOD's third largest program, with decisions yet to be made on the disposition of MRAPs in the post OIF materiel force structure, the Marine Corps has already stated MRAPS are too heavy for their expeditionary warfare.[103] Also, other tactical wheeled vehicles, such as the Joint Light Tactical Vehicle (JLTV), have been extended in early technology development as MRAPs are fielded to meet the current need.[104]

The program manager can achieve cost and schedule goals as demonstrated by the JDAM, ATACMS and MRAP case studies. However, significant factors influence the ability of DOD and the program manager to achieve those goals. Funding stability so that the program is not required to be a “program promoter” to secure funding for the program in the annual funding cycle of DOD would help promote stability. [105] The incentive structure is currently based on schedule, cost and performance ***success***, not necessarily valid projections of risk or difficulty or providing a valid program baseline.[106] The tenure and attraction of talent are also dependent on stable funding and the personnel and management chains on projects should remain in place from the inception of the project through the development phase, as industry practices.[107] The DOD acquisition management chain approves through the requirements process more programs than DOD is able to afford. The DOD acquisition management chain should examine portfolio management as a means of providing funding decisions on the services’ acquisition programs, using the QDR process to determine programs that will receive funding over the long term to provide funding stability.[108]

Accountability is also important in both public sector and defense programs, to insure public sector funds are achieving the performance and requirements originally designed for the programs. Oversight is a government responsibility and should be a function of the program office; the program office should be the program monitor, not the program promoter.[109] Several reforms to achieve more accountability are to ensure the government is providing oversight on the program, not promoting the program, and to adopt industry practices for program accountability by assuring the program management is in place for the duration of the development of the program.[110]

Conclusions

Risk management and early decision making need to go hand in hand. Most of the crucial decisions are made in the early phase of development, prior to milestone B.[111] Good decision processes must accompany good risk mitigation strategies and acquisition strategies require tailoring to the complexity and needs of the program; however, some commonalities exist. Technology risk in the form of technology immaturity and requirements risk in form of poorly defined or changing requirements have occurred in a number of programs generating cost and schedule overruns. Although producibility risk occurs and may be risk mitigated, more often, cost and schedule variances are evidence of underlying issues such as technology immaturity or requirements instability.

The three areas examined, technology, requirements and producibility are important risks to be examined in a program. The program manager and decision makers' ability to manage and control requirements is possible with courageous decisions to not allow programs to enter EMD with either poorly defined requirements or those that cannot be easily translated into technical and system solutions, and to hold requirements firm over definitive time periods. In cases where system development may take significantly longer than four or five years, evolutionary acquisition with additional milestones may help control requirements instability. Albeit, not solely in the domain of the program manager, requirements growth should be discouraged once

EMD begins. Likewise, with technology immaturity, risk may be controlled by measuring technology maturity and only allowing programs to enter EMD with TRL levels of 6 or higher for significant portions of the critical technologies.

Cost and schedule overruns occur on other than defense related projects. Railroad, highway and other large infrastructure projects such as canals and opera houses are typically over cost by significant margins, from anywhere on cost to as much as 200 percent overruns.[112] Large software projects experience similar overruns.[113] In many of these projects, as demonstrated here for defense projects, optimistic projections of value and use are at the root cause of the inflated viability of the projects. As in public sector large projects, complex defense projects are overly optimistic in the expected costs and ability of technology to provide leaps in performance in the early stages of development.[114] For transportation infrastructure projects, optimism results in a belief in unrealistic forecasts of usage, undervaluing environmental impacts, and over-inflating the regional economic benefits for transportation and large infrastructure projects.[115]

The development of a risk management plan based on the most likely scenarios as opposed to the-everything-goes-according-to-plan approach is recommended in order to provide more realism in the cost estimation of the project.[116] Managing risks can help programs achieve goals on cost, schedule and performance. Ultimately, the government benefits from the proper use of risk management to prepare for and mitigate risk to programs. By achieving these goals, the DOD is better prepared to estimate total program cost. The defense department can achieve better project performance with risk management. By including risk analysis, the feasibility of a project based on realistic costs over the life of the project will provide a better estimation of the total cost of the program or project over the program's life cycle. The Norwegian defense agency is adopting just such an approach.[117]

The DOD acquisition system is not meant to be, nor should it be, a "one size fits all" approach. Software development is different from large infrastructure building development is different from technologically mature weapons systems is different from technologically complex systems. Tailoring the program to specific needs is the type flexibility that DOD requires to manage programs. Some large complex programs will need significant risk management programs, other less technologically complex programs may not. Complex software development efforts, and other non-defense programs also experience cost and schedule overruns. Risk management may mitigate some of the risks in a program. However, risk management is not a single source solution for the complex management of uncertainty in a program. Risk management when coupled with other techniques such as decision analysis may help a program manager in early identification of potential sources of cost and schedule growth as parts of a robust, continuous management approach.

Recommendations for Further Investigation

In some of the case studies examined, the decision processes that have allowed programs with poorly defined or changing requirements or immature technologies to enter into EMD is an area of investigation that would be beneficial to DOD. The implication of the FCS program is that the program was entered into EMD with poorly defined requirements and immature technologies, and both were known prior to entry into EMD. The decision processes that lead to these conditions should be examined.

Some research infers that the Planning, Programming, Budgeting and Execution System (PPBES) and program advocacy by program acquisition personnel lead to poor decision analysis with Milestone Decision Authorities (MDA).[118] Others suggest that risk adverse managers are driving poor decisions and that the system promotes limited information flow to decision makers.[119] Budget driving decisions and success oriented programs are areas in need of further investigation.

Some analyses have correlated funding instability with personnel turnover.[120] An area of further study would be the correlation of turnover and tenure with program success. If more responsibility is delegated to program managers to control technology and requirements, some thought about how long the program managers should be with the program, perhaps from advanced development through EMD should be examined with program success. That same tenure investigation might be applied to the acquisition decision makers in the decision chain.

The certification of acquisition professionals in program management offices and in the decision chains might be correlated with program success as another area for further study. A study on the correlation of training acquisition professionals with program management certifications, and the success of programs may be illustrative of the knowledge needed for successful programs.

The volume of contractual, legal and acquisition oversight complicates approvals of program documentation and has impacts on schedules.[121] An area of study would be the impacts of congressional intervention that micro-manages the system with oversight processes and the impacts of those interventions on the program success.

Acquisition program performance can and should be improved. Cost and schedule overruns due to immature technology or requirements instability should not occur on a regular basis. And yet on the FCS and the F-22 approvals for entry into EMD with both immature technologies and requirements changes occurred. Risk management can provide a method to identify the risks with immature technology and requirements instability. However, these tools need to be used with courageous decisions by program managers and decision makers at service and DOD leadership alike to disapprove programs that are not ready for EMD. Better program management will improve fiscal and schedule performance. Other elements of the acquisition system need improvement such as encouraging Congress to allow portfolio funding flexibility and the PPBE linking multiyear funding commitment to EMD start. As Secretary Gates stated on release of the 2010 DOD budget and in front of congress: "We must constantly guard against so-called "requirements creep," validate the maturity of technology at milestones, fund programs to independent cost estimates, and demand stricter contract terms and conditions. I am confident that if we stick to these steps, we will significantly improve the performance of our defense acquisition programs. But it takes more than mere pronouncements or fancy studies or reports. It takes acting on these principles by making **tough decisions** [emphasis added] and sticking to them going forward."[122]

Endnotes

[1] The White House, Office of the Press Secretary, May 22, 2009, Remarks by the President at Signing of the Weapons Systems Acquisition Reform Act, http://www.whitehouse.gov/the_press_office/Remarks-by-the-President-at-signing-of-the-Weapons-Systems-Acquisition-Reform-Act/, accessed November 15, 2009.

[2] Moshe Schwartz, Congressional Research Service Report for Congress, RL34026, Defense *Acquisitions: How DOD Acquires Weapon Systems and Recent Efforts to Reform the Process*. (Washington, DC: Congressional Research Service, July 10, 2009), 13.

[3] Many Washington-based think tanks and GAO reports have been critical of the Defense acquisition programs. The GAO report listed here is the assessment of 72 programs; RAND, the Center for Strategic and International Studies (CSIS), Business Executives for National Security (BENS) and the Heritage Foundation have all funded and produced reports that describe desired improvements into defense acquisition. The major sources are listed here:

- Christopher H. Hanks et al. *Reexamining Military Acquisition Reform: Are We There Yet?* (Washington DC, The RAND Corporation, 2005), 1, 34, 46, 58.

- Clark A. Murdock and Michele A. Flournoy, *Beyond Goldwater-Nichols: U.S. Government and Defense Reform for a New Strategic Era Phase 2 Report.* (Washington DC, Center for Strategic and International Studies (CSIS), July 2005), 6, 7, 10, 11.

- Norman R. Augustine et al. *Getting to Best: Reforming the Defense Acquisition Enterprise*. (Washington, DC, Business Executives for National Security, July 2009), 1-13.

- Baker Spring, “Congressional Restraint Is Key to Successful Defense Acquisition Reform,” Heritage Foundation Backgrounder, No. 1885 (Washington DC, October 19, 2005) No. 1885, 1-9.

- LTG Ronald Kadish (Ret) et al, *Defense Acquisition Performance Assessment Report* (Washington, DC, Defense Acquisition Performance Assessment Project, January 2006), 36, 49, 69.

- Katherine V. Schinasi, Testimony Before the Committee on Armed Services, U.S. Senate, U.S. Government Accountability Officer, DEFENSE ACQUISITIONS: Better Weapon Program Outcomes Require Discipline, Accountability, and Fundamental Changes in the Acquisition Environment, (Washington, DC, US General Accountability Office, June 3, 2008), 2.

[4] U.S. Government Accounting Office, DEFENSE ACQUISITIONS: Assessments of Selected Weapon Programs, Report to Congressional Committees, (Washington, DC, U.S. Government Accounting Office, March 2008), 7.

[5] U.S. Defense Acquisition University, RISK MANAGEMENT GUIDE FOR DOD ACQUISITION, fifth edition, Fifth Edition (Fort Belvoir, Virginia: U.S. Defense Acquisition University Press, September June 2002), 7.

[6] Ibid.

[7] Ibid. Sometimes, a third component is added - a future root cause. If the future root cause is modified or eliminated, the root cause risk would be prevented or at least lessen the impact of a consequence associated with the root cause. Although managing risk with this future root cause is important, in terms of use in the risk process, the consequence and probability of

occurrence determine the overall risk level, and root causes are more closely associated with program individual characteristics. This paper addresses consequences and probability as the two components of risk and not the future root cause in assessing risk to a program.

[8] Ibid.

[9] U.S. Defense Acquisition University, RISK MANAGEMENT GUIDE FOR DOD ACQUISITION, Fifth Edition (Fort Belvoir, Virginia: U.S. Defense Acquisition University Press, September June 2002), 8.

[10] Jeff Veselenak, "The Value of Risk Management in Acquisition Planning," *Contract Management* 49, no. 5 (May 2009): 56. Various combinations of the steps depicted in figure 1 of the risk management cycle exist, in the Defense Acquisition University guides and in the Project Management literature. All infer a cycle and various others move subordinate steps in the risk assessment process to major steps in the risk management cycle. I chose this cycle because the prioritization steps are subordinate to the Assessment phase, also called analysis by other sources.

[11] Ibid, 58-59. Planning for a well executed and run risk management program is a complex management endeavor. Also see the DAU risk management guides referenced early as well as other program risk management sources cited in these endnotes for a more comprehensive review of risk management planning.

[12] The areas addressed in a risk management planning were compiled from:

- Dr. Harold Kerzner, Project Management: A Systems Approach to Planning, Scheduling and Controlling, 9th Edition, (Hoboken, New Jersey: John Wiley & Sons, 2006), 723.

- Richard B. Barber, "Understanding Internally Generated Risks in Projects," *International Journal of Project Management*, 23, (2005), 588.

- David Baldry, "The Evaluation of Risk Management in the Public Sector Capital Projects," *International Journal of Project Management*, 16, No. 1, 35-41.

[13] Ibid., 60. Other areas of risk are covered in U.S. Defense Acquisition University's RISK MANAGEMENT GUIDE FOR DOD ACQUISITION, sixth edition on page 9.

[14] Veselenak, "The Value of Risk Management in Acquisition Planning," 60.

[15] Steve Hoeft, Melinda Davey, Dean Newsome, "Proactively Managing Risk, The New 'Waste'," *Defense AT&L*,36, no. 3 (May-June 2007), 38-39. . Value stream mapping is a technique to map work and material flow processes and is an additional technique along with a WBS to assist in a proactively identifying risks.

[16] U.S. Defense Acquisition University, RISK MANAGEMENTGUIDE FOR DOD ACQUISITION, fifth edition, 7-8.

[17] Douglas J. Bragdon, "First Things First, The Importance of Risk Identification," *Defense AT&L* 36, no. 3 (May-June 2007): 14-15.

[18] Ibid., 15.

[19] Terry M. Williams, "Using a Risk Register to Integrate Risk Management in Project Definition," *International Journal of Project Management*, 12, No. 1, (1994), 18. Risk registers are particular invaluable on large, complex projects. The register provides the means for cataloguing and monitoring risks by identification, plan and measurement activities.

[20] U.S. Defense Acquisition University, RISK MANAGEMENTGUIDE FOR DOD ACQUISITION, sixth edition, 12-16.

[21] Veselenak, "The Value of Risk Management in Acquisition Planning," 62-63. This sets the risk management matrix into a green, amber, red or stoplight format and begins to highlight those amber and above for risk mitigation. For example, a risk may have a cost impact to the program and the program may establish the scale at little to no impact (less than 0.5% cost growth), 1%, 5% (usually the amber level is set at 3), 10% and greater than 10%. The scales may be linear or logarithmic and may address any of the risk categories previously mentioned. The rankings are on a scale to provide a matrix for managing risk from least likely to most likely to occur (or probability) and from no impact to a highly severe impact (or consequence or severity). The severity is usually assigned to broad categories of cost, schedule or performance, and sometimes other elements of the WBS.

[22] The Risk Reporting Matrix is compiled from four sources.

- Aerospace Corporation, Risk Management Quick Reference Card, 2003, 1-2.
- National Aeronautics and Space Administration (NASA), Systems Engineering Handbook, (Washington DC: NASA Center for Aerospace Information, Hanover, MD, December 2007), 139-150.
- U.S. Defense Acquisition University, RISK MANAGEMENTGUIDE FOR DOD ACQUISITION, sixth edition, 11-17.
- Institute of Risk Management (IRM), A Risk Management Standard, (London, UK: IRM, 2002), 6-8.

Many of the scales are in five levels. Risk Matrices are about visual presentation, to rapidly identify the high probability, high consequence (red), medium probability, medium consequence (amber), and lower consequence, lower probability (green) risks. As you can see in the table with definitions, the consequence levels may be in many different forms, but the probability is usually a percentage of likely occurrences. The schema may be more elaborate as the risk situation necessitates and the plan should have a consequence and probability scale for each risk. In general, the amber or red risks are identified for some form of action. Even a green risk may be monitored if the risk is judged to be such a high consequence to the program that the item will need to be monitored. In general, this allows a quick pictorial stoplight chart that quickly identifies those risks that are being addressed. This pictorial is not static. Mitigation plans may indeed reduce the probability and so the risk itself becomes less of an issue for the program. For large programs, the risks are identified by number and placed on the chart and movement is tracked to indicate increasing or decreasing probability or consequence as the risk is measured. Ideally you would like to see the risks move from the red quadrants to the green.

[23] Veselenak, “The Value of Risk Management in Acquisition Planning,” 62-63.

[24] U.S. Defense Acquisition University, RISK MANAGEMENTGUIDE FOR DOD ACQUISITION, Fifth Edition, 21-24. For a more exhaustive and authoritative treatment of the various risk mitigation techniques and strategies, especially in the control area, see Edmund R. Conrow, Effective *Risk Management: Some Keys to Success*, (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 2003), 29-32, 365-387.

[25] Ibid., 23-24.

[26] John T. Dillard and David N/ Ford, “From Amorphous to Defined: Balancing Risks in Evolutionary Acquisition,” *Defense Acquisition Review Journal*, 12, No. 3, (October 2009), 248-249.

[27] Ibid., 249.

[28] Risk management has become an integrated part of the education of institutional program management, being incorporated into instructional materials for the profession. Two references are provided here, one for engineering program management to provide context for program management risk analysis, and one reference that advocates that all large program management public sector projects have a risk management process:

- Flyvbjerg, Megaprojects and Risk, 73-85
- Kerzner, “Risk Management,” Project Management, 707-765.

[29] Kerzner, Project Management, 614-620. The rest of this chapter also describes work breakdown structures and other program management functions like cost base-lining. Also see chapter 17 for a good summary of risk management now being applied to program management training.

[30] Many reports and books have been written on program management cost and schedule overruns. Three are mentioned here as references, one each from the commercial, public and defense sectors:

- Kerzner, Project Management, 638-9.
- Bent Flyvbjerg, Nils Bruzelius, and Werner Rothengatter, Megaprojects and Risk: An Anatomy of Ambition, (Cambridge, United Kingdom: Cambridge University Press, 2003), 11-21.
- U.S. Government Accounting Office, DEFENSE ACQUISITIONS: Assessments of Selected Weapon Programs, Report to Congressional Committees, 7.

[31] U.S. Government Accounting Office, DEFENSE ACQUISITIONS: Assessments of Selected Weapon Programs, Report to Congressional Committees, Highlights, 0.

[32] U.S. Department of Defense, Defense Acquisition Guidebook (Washington D.C. 12/17/2009), https://acc.dau.mil/CommunityBrowser.aspx?id=323139#10.5.2, (Accessed December 27, 2009).

[33] United States Code (USC) Title 10, Subtitle A, Part IV, Chapter 139, Section 2366b, "Major Defense Acquisition Programs: Certification Required before Milestone B Approval, 2009 version, accessed http://www.law.cornell.edu/uscode/10/usc_sec_10_00002366---b000-.html. This section of Title 10 requires the Material Decision Authority to sign a certification that the "technology in the program has been demonstrated in a relevant environment," which is TRL level 6.

[34] Table 1 was compiled from several sources:

- Dillard, "From Amorphous to Defined: Balancing Risks in Evolutionary Acquisition," *Defense Acquisition Review Journal*, 12, No. 3, (October 2009), 243.

- Ronald O'Rourke, Congressional Research Service Report, Air Force F-22 Fighter Program: Background and Issues for Congress, (Washington, DC, U.S. Congressional Research Service, September 11, 2009), 3, 8, 12.

- Dominique Myers, "Acquisition reform--inside the silver bullet: A comparative analysis--JDAM versus F-22," *Acquisition Review Quarterly*, 9, No. 4 (Fall 2002), 312-320.

- U.S. Government Accounting Office, DEFENSE ACQUISITIONS: Improved Business Case Is Needed for Future Combat System's Successful Outcome, Report to Congressional Committees, (Washington, D.C, March 2006), 16-18.

- U.S. Government Accounting Office, DEFENSE ACQUISITIONS: Improved 2009 Review of Future Combat System Is Critical to Program's Direction, Report to Congressional Committees, (Washington, D.C, April 2008), 4-6.

- U.S. Government Accounting Office, Issues Facing the Army's Future Combat Systems Program, Report to Congressional Committees, (Washington, D.C, August 13, 2003), 25.

[35] David Grilliot and Cory Hatch, "Multiple Launch Rocket System (MLRS) Fuzing Evolving to Meet End User Requirements", 51st Annual NDIA Fuze Conference, 23 May 2007

[36] Dillard, "From Amorphous to Defined: Balancing Risks in Evolutionary Acquisition," *Defense Acquisition Review Journal*, 12, No. 3, (October 2009), 243.

[37] JOINT DIRECT ATTACK MUNITION (JDAM) Pilot Program Consulting Group (PPCG) 1997 Compendium of Pilot Program Reports, Office of the Deputy Under Secretary of Defense (Acquisition Reform), 1997, http://www.fas.org/man/dod-101/sys/smart/ppcp97c1.htm, accessed on 29 Dec 2009.

[38] Dillard, "From Amorphous to Defined: Balancing Risks in Evolutionary Acquisition," 243.

[39] Dillard, "From Amorphous to Defined: Balancing Risks in Evolutionary Acquisition," 242-244.

[40] Ibid.

[41] Young Hoon Kwak and Brian M. Smith, “Managing risks in mega defense acquisition projects: Performance, policy and opportunities,” International Journal of Project Management, 27, Issue 8, (November 2009) 819-820.

[42] U.S. Government Accounting Office, Issues Facing the Army’s Future Combat Systems Program, Report to Congressional Committees, (Washington, D.C, August 13, 2003), 25

[43] U.S. Government Accounting Office, DEFENSE ACQUISITIONS: Improved Business Case Is Needed for Future Combat System’s Successful Outcome, Report to Congressional Committees, (Washington, D.C, March 2006), 17.

[44] U.S. Government Accountability Office, DEFENSE ACQUISITIONS: 2009 Review of Future Combat System is Critical to Program’s Direction, (Washington, D.C., April 2008), 1.

[45] Obaid Younossi et al, Lessons Learned from the F/A–22 and F/A–18 E/F Development Programs, (Rand Corporation, Arlington, Virginia: 2005), 29-33.

[46] U.S. General Accounting Office, F-22 AIRCRAFT: Progress in Achieving Engineering and Manufacturing Development Goals (Washington, D.C., March 1998), 3.

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[49] Steven Meier, “Best Project Management and Systems Engineering Practices in the Preacquisition Phase for Federal Intelligence and Defense Agencies,” Project Management Journal, 39, No. 1 (March 2008), 64.

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[51] Ibid., 64.

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[54] J. Daniel Sherman, “Lessons Learned from the Development of the Joint Stand-Off Target Attack Radar System Common Ground Station,” *Defense Acquisition Review Journal*, Supplemental Issue, 13, Issue 1 (2006), 88-89.

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[59] Ibid., 64.

[60] U.S. Department of Defense, *Joint Capabilities Integration and Development System.* Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3170.01G, (Washington, D.C.: U.S. Department of Defense: 1 March 2009), enclosure A-1.

[61] U.S. Government Accountability Office, DEFENSE ACQUISITIONS: DOD’s Requirements Determination Process Has Not Been Effective in Prioritizing Joint Capabilities, (Washington, DC, U.S. Government Accountability Office, September 2008), 2-3.

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Subcommittee on AirLand, Committee on Armed Services, U.S. Senate, (Washington, DC, U.S. Government Accountability Office, April 2005), 5-6.

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[78] Cynthia Ingols and Lisa Brem, Implementing Acquisition Reform: A Case Study on Joint Direct Attack Munitions, (Fort Belvoir, VA: Defense Systems Management College, July 1988), 11-15.

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[120] Lucas, “Lessons from the Development of Army Systems,” 120.

[121] U.S. Government Accounting Office, BEST PRACTICES: Better Support to Program Managers Needed to Improve Outcomes, 46.

[122] Defense Budget Recommendation Statement (Arlington, VA) As Prepared for Delivery by Secretary of Defense Robert M. Gates, Arlington, VA, Monday, April 06, 2009, http://www.defense.gov/Speeches/Speech.aspx?SpeechID=1341, (accessed 9 Feb 2010).